

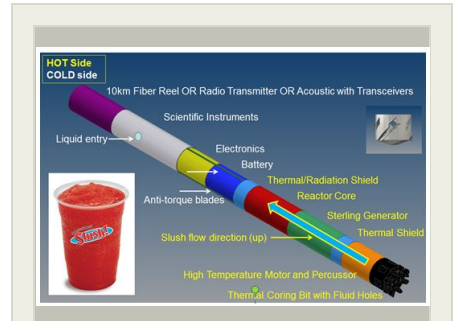
## SLUSH: Europa Hybrid Deep Drill, Phase I

Completed Technology Project (2017 - 2017)



## Project Introduction

There are at least two fundamental design approaches one could use when trying to penetrate the icy shell on Europa and other planetary bodies: a melt probe and an electro-mechanical drill. A melt probe uses a hot point to melt through ice and penetrate downward. In this regard, it is a very simple approach - it requires a heat source. However, the power required to melt 50-110K ice is 10s of kW, of which 90% is lost into the surrounding ice. In addition, melt probes will not penetrate anything else but ice, and if the heat is provided by integrated RTGs, the probe will overheat and melt if the conductive properties of ice change (e.g. if ice becomes porous, it will become a very good insulator). The electro-mechanical approach is an order of magnitude more energy efficient than a melt probe. However, the drill needs to get rid of the cuttings it is generating. The drill can also freeze in-place if it encounters any liquid water. Numerous drills deployed in Antarctica, for example, froze in-place while drilling down the borehole, because ice tuned into liquid water at the cutter-ice interface. We therefore propose a Hybrid approach that takes the best of both worlds and reduces risks posed by each of the options above. SLUSH is a hot-point electro-mechanical drill that cuts through ice using rotary-percussive action, and melts chips with its hot bit to form slush. The slush moves up the hole where it refreezes behind the drill. SLUSH is approximately 14 cm in diameter and 2.5 m long. Because SLUSH uses mechanical action to break ice, it is significantly faster than a melt probe and also significantly more efficient, since slush does not have as much time to loose heat into the surrounding ice. Since SLUSH uses a hammer drill, it can also penetrate material with a significant fraction of insoluble material (e.g. silt). An added benefit of SLUSH is that science instruments can draw liquid directly from the outside for analysis.



SLUSH: Europa Hybrid Deep Drill, Phase I Briefing Chart Image

## Table of Contents

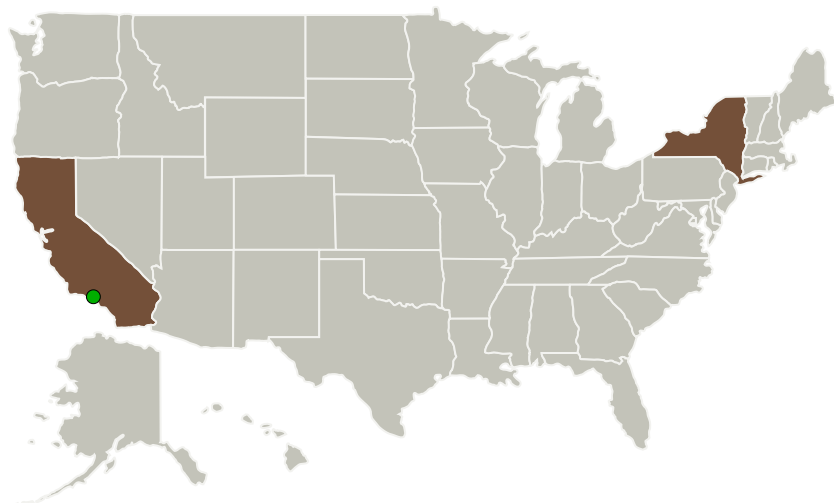
Project Introduction	1
Primary U.S. Work Locations and Key Partners	2
Organizational Responsibility	2
Project Management	2
Technology Maturity (TRL)	2
Images	3
Technology Areas	3
Target Destinations	3

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## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Honeybee Robotics, Ltd.	Lead Organization	Industry	Pasadena, California
● Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California

## Primary U.S. Work Locations

California	New York
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## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

Honeybee Robotics, Ltd.

**Responsible Program:**

Small Business Innovation Research/Small Business Tech Transfer

## Project Management

**Program Director:**

Jason L Kessler

**Program Manager:**

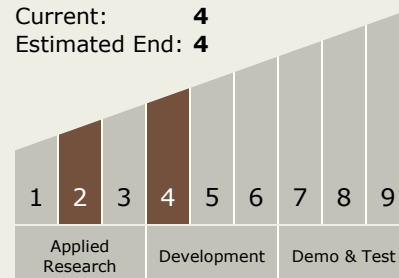
Carlos Torrez

**Principal Investigator:**

Kris Zacny

## Technology Maturity (TRL)

Start: 2  
 Current: 4  
 Estimated End: 4

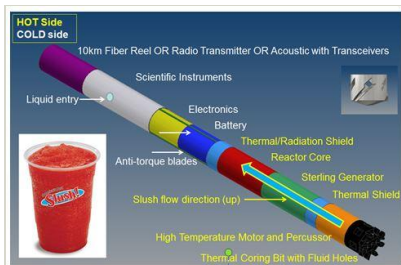


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## Images



### Briefing Chart Image

SLUSH: Europa Hybrid Deep Drill,  
Phase I Briefing Chart Image  
(<https://techport.nasa.gov/image/137274>)

## Technology Areas

### Primary:

- TX04 Robotic Systems
  - └ TX04.2 Mobility
    - └ TX04.2.4 Surface Mobility

## Target Destinations

The Sun, Earth, The Moon,  
Mars, Others Inside the Solar  
System, Outside the Solar  
System